Status of Hydrogenated Microcrystalline Silicon Solar Cells at United Solar

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ABSTRACT

We have studied the performance of hydrogenated microcrystalline silicon (μc-Si:H) solar cells using three different deposition techniques. Deposition rates ranging from low (~1Å/s), to medium (~3-10 Å/s), to high (~20 - 30 Å/s) have been obtained by using conventional radio frequency (RF), modified very high frequency (MVHF), and microwave (μ-wave) excitations, respectively; initial active-area efficiencies of 7.4%, 7.1%, and 4.9% have been achieved for the respective techniques in a single-junction structure. Double-junction cells using a-Si:H in the top and μc-Si:H in the bottom have yielded initial active-area efficiencies of 13% and 12.3% for RF and MVHF techniques, respectively. Stability and other issues will be reported.

1. Introduction

Hydrogenated microcrystalline silicon (μc-Si:H) has received a great deal of attention as a potential substitute for the more costly low band gap a-SiGe alloys [1, 2]. However, due to the low absorption coefficient, a thick (> 1 μm) intrinsic layer is needed to generate sufficient current for photovoltaic applications. It is therefore desirable to deposit good quality μc-Si:H at high rates. In this study, we employed three different glow-discharge techniques, RF, MVHF, and μ-wave, to deposit μc-Si:H at low (~ 1Å/s), medium (3-10 Å/s), and high (~ 20 – 30 Å/s) growth rates to evaluate the corresponding solar cell performance. While the RF and MVHF deposited cells exhibit similar efficiencies, the high rate μ-wave deposited cells show much lower short-circuit current density, hence lower efficiency.

2. Experimental

Multi-chamber systems are used for this study. Single-junction *n-i-p* solar cells with μc-Si:H as the *i* layer were deposited using RF at 13.56 MHz, MVHF at 70 MHz, and μ-wave at 2.45 GHz onto 4 cm x 4 cm stainless steel substrates precoated with textured silver/zinc oxide back reflectors. Indium tin oxide dots with 0.25 cm^2 active area were deposited on top of the *p* layer as the top contact. Deposition conditions were adjusted to optimize cell efficiencies. Double-junction cells were made using μc-Si:H in the bottom *i* layer and a-Si:H in the top *i* layer.

3. Results and Discussion

Figures 1 and 2 plot J-V characteristic and quantum efficiency for three *n-i-p* solar cells made by RF, MVHF, and μ-wave techniques, showing initial active-area efficiencies of 7.4%, 7.1%, and 4.9%, respectively. While cells made by RF and VHF exhibit similar characteristics, the μ-wave deposited cell shows much lower current. Although the reason for the low current is not fully understood, x-ray diffraction and Raman spectroscopy data did reveal lower microcrystalline volume fraction and smaller grain size for the μ-wave deposited films. More details are given in a separate paper [3].

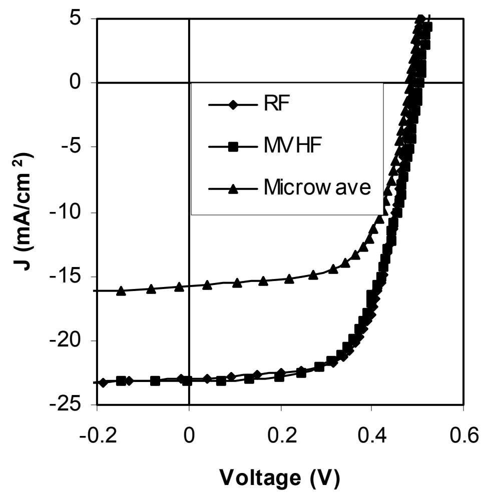

Figure 1. J-V characteristics of RF, MVHF, and μ-wave deposited μc-Si:H single-junction cells.

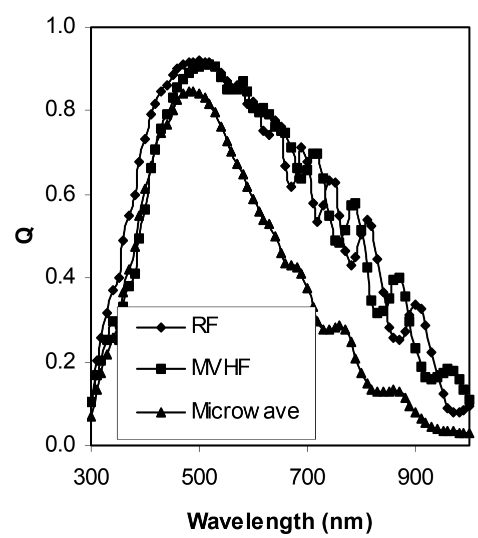

Figure 2. Quantum efficiencies of RF, MVHF, and μ-wave deposited μc-Si:H single-junction cells as shown in Fig.1.

Table I. Stability of a-Si:H/μc-Si:H double-junction cells with 0.25 cm^2 active area using RF and MVHF.

Sample No.	State	Eff. (%)	J_{sc} (mA/cm^2)		V_{oc} (V)	FF
			Top	Bottom		
RF 14066	Initial	12.29	12.15	11.31	1.420	0.765
	Stable	11.15	11.48	11.25	1.396	0.710
	Degradation	9.3%	5.5%	0.5%	1.7%	7.2%
MVHF 11568	Initial	11.62	12.15	10.96	1.386	0.765
	Stable	10.24	11.47	10.89	1.351	0.696
	Degradation	11.9%	6.1%	0.6%	2.5%	9.0%

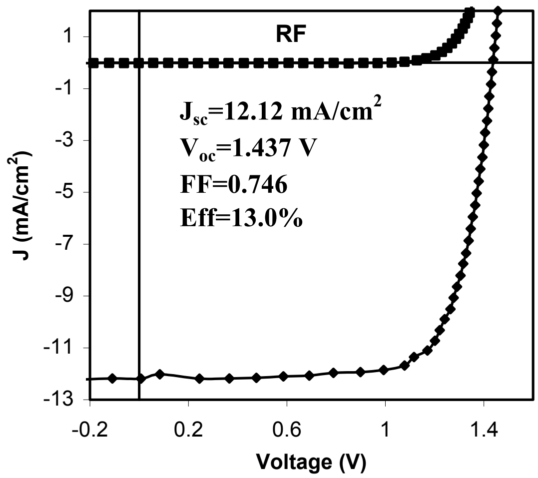

Figure 3. J-V characteristics of the best a-Si:H/μc-Si:H double-junction cell by RF.

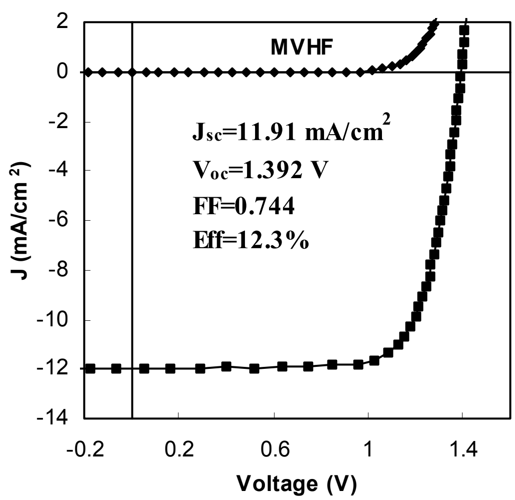

Figure 4. J-V characteristics of the best a-Si:H/μc-Si:H double-junction cell by MVHF.

As a first step to evaluate μc-Si:H as a potential candidate for substituting a-SiGe:H alloys, we have made double-junction cells by incorporating μc-Si:H in the bottom *i* layer and a-Si:H in the top using RF and MVHF techniques; Figs. 3 and 4 display the respective initial J-V characteristics for the two structures. Although the deposition rate for MVHF is at least 3 times higher than RF, the initial cell efficiency of 12.3% is only slightly lower than the 13% value obtained from RF. We have also light soaked the two double-junction structures under one-sun, 50 °C, and open-circuit conditions for 1,000 hours; the results are summarized in Table I. Stable efficiencies of 11.1% for RF and 10.2% for MVHF have been achieved. Efforts on improving μc-Si:H quality and investigating other multijunction structures are under way.

4. Summary

We have used RF, MVHF, and μ-wave to deposit μc-SI:H at different rates and achieved 7.4%, 7.1%, and 4.9% initial active-area efficiencies, respectively, in single-junction *n-i-p* solar cells. We find that μ-wave deposited cells show low current, thus low efficiency. Double-junction cells using a-Si:H in the top *i* layer showed 13% and 12.3% initial active-area efficiencies for RF and MVHF depositions, respectively. Double-junction structures with RF and MVHF typically retain 90% of the initial efficiency after long-term light exposure.

5. Acknowledgment

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